ROY F. WESTON, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

ORIGINAL (Red)

9 January 1973

Mr. Lester F. Meyer
Delaware Division of Environmental Control
Water Pollution Section
Tatnall Building
Dover, Delaware 19901

Dear Duffy:

Enclosed is a copy of our latest report on the ground water pollution situation at the Llangollen Landfill in New Castle County. [illegible] proposed work outlined at the end of the report will begin the [illegible] of January 15th with drilling and testing of potential leachate [illegible]overy wells between the landfill and the Artesian Water Company well field. Please do not hesitate to contact me with your comments.

Sincerely yours,

Mickey

Michael A. Apgar

P.S. *I have also attached a tabulation of our water analyses results* on the samples you collected at Llangollen with Roger Gresh and Mark Horner on December 19th. Wells DC 14-13 and DC 24-6 are observation wells belonging to Amoco Chemical Corporation. Their locations are shown on Figure 3 of the enclosed report. Neither well had been previously sampled, and I understand that you had to rush your samples back to the lab and were not present when the two wells were pumped late that afternoon.

Well 14-13 is uncontaminated, because it is probably not in the leachate flowpath and also because it is screened in a relatively clayey unit along which leachate would probably not have invaded anyway.

Well 24-6 is slightly contaminated--either by the Llangollen Landfill or the Delaware Sand and Gravel Co. fill. If from Llangollen, contaminants have moved at least 2000 ft. through the subsurface to date.

I would appreciate receiving copies of your analytical results on the other water samples collected that day. I will need permits for the proposed wells to be drilled next week. I will be in contact with you in a few days when the exact starting date for drilling [illegible] firmed up.

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Roy F. Weston Results of Analyses on Water Samples
Collected Jointly With DEC on December 19, 1972,
From Wells in the Vicinity of the Llangollen Landfill:

Well	Temperature	Specific Conductance (umhos/cm)	Cl (ppm)	Comments
Robelens	61	69	11	Clear, odorless
1A	57	90	11	Clear, odorless
3A	61	1100	128	Slightly turbid, (milky) and foul odor
Dc 14-13	56	54	6	Slightly turbid odorless
Dc 24-6	57	170	30	Gray-brown tinge with slight turbidity, slight organic (oily) odor

ROY F. WESTON, INC.

[illegible]

ORIGINAL (Red)

5 January 1973

Mr. [illegible]
[illegible] Division [illegible] Control
[illegible]
[illegible] Building
[illegible]

Dear Sally:

Enclosed is a copy of [illegible] report on the Llangollen Landfill situation which covers work done through the end of September, 1972. This report includes all background information and water quality analyses [illegible].

Information from the October/November test drilling project which [illegible] in your office on December 14, 1972, is being typed. [illegible] second report includes the extent of contamination in the [illegible] aquifer, estimates on the rate of contaminant movement, and [illegible] contaminants reach the major pumping wells. The report [illegible] an outline of corrected procedures [illegible] recovery wells. This work should begin [illegible] 15.

Sincerely yours,

[illegible]

Michael A. Apgar
Hydrogeologist

MAA:cdb

Enc.

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GROUND WATER CONTAMINATION ASSOCIATED WITH THE
LLANGOLLEN LANDFILL, NEW CASTLE COUNTY, DELAWARE

EXTENT OF CONTAMINATION AND PROPOSED CORRECTIVE PROCEDURES

JANUARY 1973

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The Llangollen Landfill was constructed from 1960 to 1968 in a depleted sand and gravel quarry. The landfill is approximately 4400 feet long, 250 to 900 feet wide and 30 to 50 feet thick. The location of the landfill is shown in Figure 1.

Hydrogeologic Setting

The sand excavated from the quarry was Pleistocene age. In the Llangollen area these sands, known as the Columbia Formation, form a nearly continuous surficial cover up to 60 feet in thickness. The base of the formation ranges from about 10 feet above to 20 feet below mean sea level in the vicinity of the landfill.

The underlying Potomac Formation consists of stream-deposited unconsolidated sands, silts and clays of Lower Cretaceous Age. The sand units are channel-shaped, with extensive interbedded lenses of clay and silt which accumulated on ancient floodplains. The Potomac Formation thickens and dips towards the southeast at approximately 40 to 140 feet per mile (uppermost and lowermost beds respectively) in the study area.

Hydrologically the generally coarse Columbia deposits serve as an infiltration and recharge gallery for the Potomac sands. Ground water in the Potomac sands becomes confined (artesian) beneath relatively impermeable beds of clay and silt as it travels seaward down dip in the formation. The approximate thickness of the Potomac confining units immediately beneath the Columbia sands are shown in Figure 2. Immediately beneath the landfill these clay and silt deposits are shallow, thin or--in the area off the southeast corner of the fill--absent.

Landfill construction in the open pit proceeded from east to west. Refuse covering operations were conducted by the quarry operator, using the quarrying equipment which was already on the site. Nearly all intermittent cover material was obtained within the pit from waste piles and siltation basins. As time progressed, cover material and landfill space became critically depleted--a situation which encouraged deeper excavation on the western end of the pit. This excavation removed some--and in a few places probably all--of the confining clay on top of

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FIGURE 1

PORTION OF WILMINGTON SOUTH U.S.G.S. 7½ MINUTE TOPOGRAPHIC MAP SHOWING THE LOCATIONS OF THE LLANGOLLEN LANDFILL AND ALL WELLS AND BORINGS IN ITS VICINITY, SEPTEMBER, 1972

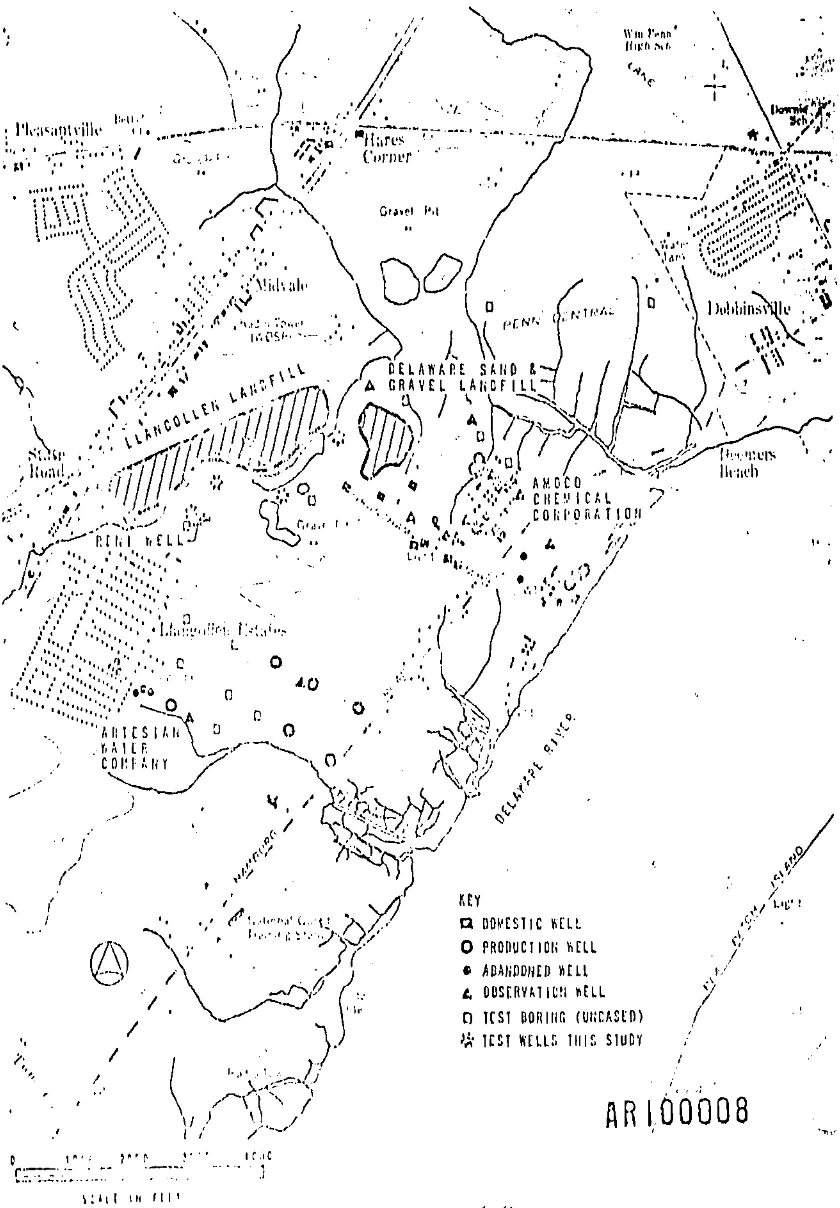

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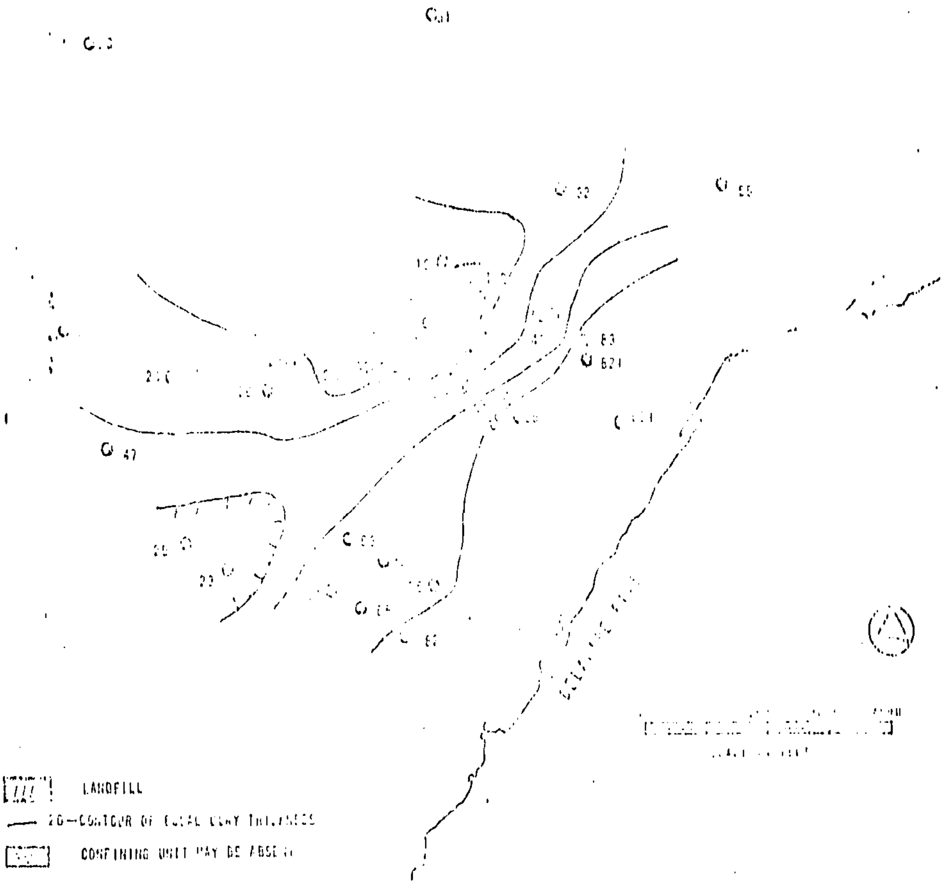
FIGURE 2

ISOPACH MAP OF THE RED CLAY CONFINING UNIT AT THE TOP OF THE POTOMAC FORMATION IN THE VICINITY OF THE [illegible]



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the Potomac sands. Such conditions permitted direct access to the Potomac sands by leachate from the landfill.

Ground Water Movement

Under natural conditions, water entered the Potomac sands where they subcropped beneath the permeable Pleistocene sediments. This water moved slowly downdip in the formation to be discharged to the Delaware Estuary or Atlantic Ocean by vertical leakage. However, the rate of ground water movement has been greatly accelerated locally by heavy pumpage by the Amoco Chemical Corporation (about 2.5 mgd) and the Artesian Water Company (about 4.5 mgd). The locations of both these well fields are shown on Figure 3.

In August and September, 1972, 10 test wells were drilled to different depths at 4 locations in the vicinity of the landfill. During October and November, 9 additional test borings were made and completed with piezometers for water level measurement. A generalized piezometric map of the Potomac sands utilizing data from measurements made in these wells and a few industrial observation wells in September and December, 1972, and the major production wells in September is shown in Figure 3. The theoretical direction of ground water movement (shown on the figure) is perpendicular to the piezometric contours. However, in actuality, ground water will tend to move along the sand and gravel-filled channels--avenues along which the permeability is greatest. Unfortunately, both the piezometric gradient and the permeable channels trend towards the high capacity pumping wells.

The average rate of movement of a slug of water through the aquifer, can be approximated by the expression:

(1) $V = KI$,

where V = average apparent velocity
K = coefficient of permeability of the media
I = hydraulic gradient

The maximum coefficient of permeability along the Potomac channel deposits is probably on the order of 1000 gpd/ft^2 (the permeability of a clean, fine gravel).

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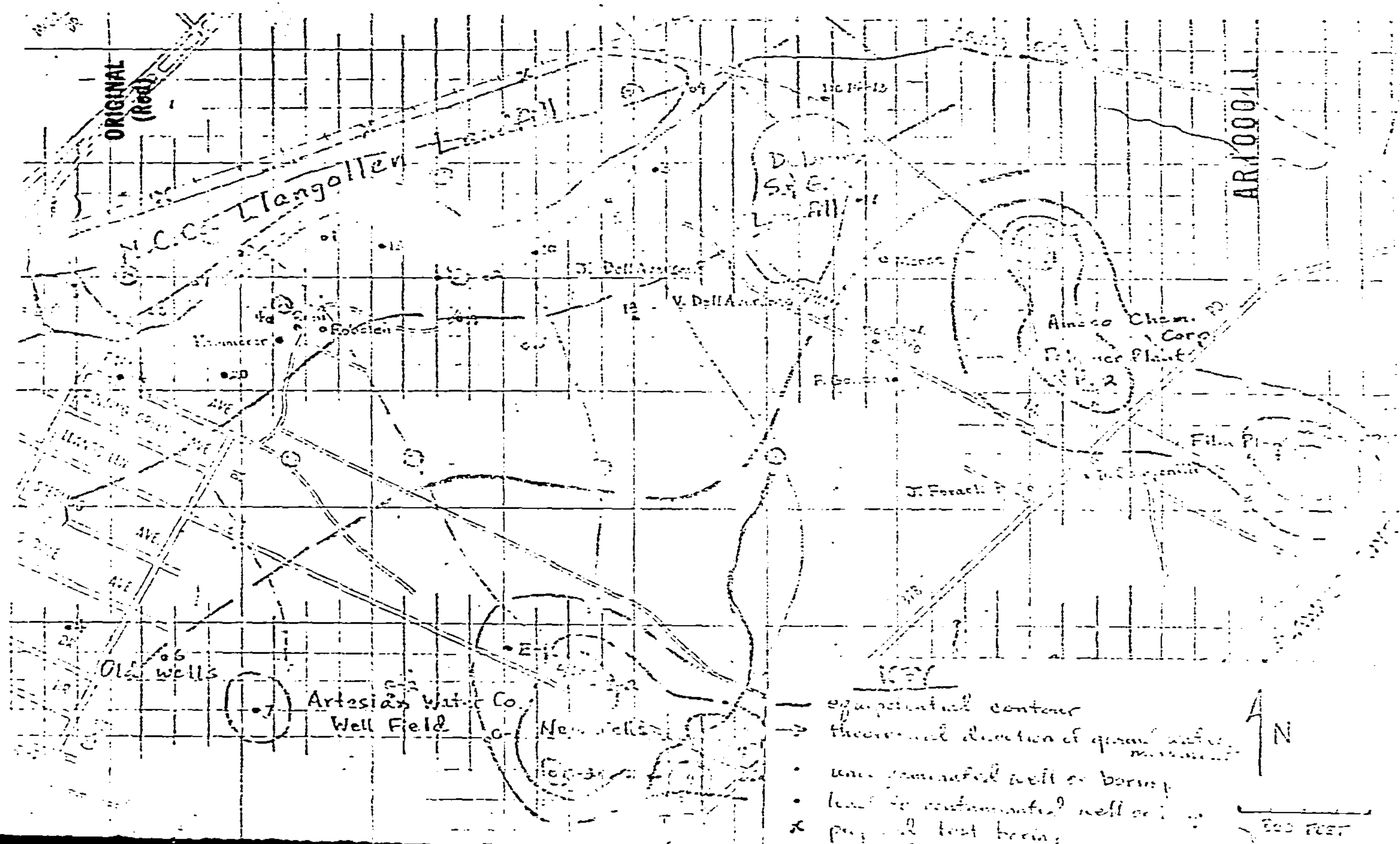
FIGURE 3 - MAP OF THE LLANGOLLEN LANDFILL VICINITY SHOWING WATER FLOW DIRECTIONS IN THE UPPER POTOMAC AQUIFER. ALSO SHOWN ARE WATER QUALITY INTERPRETATIONS FOR WELLS AND TEST BORINGS AND THE LOCATIONS OF PROPOSED TEST BORINGS AND LEACHATE MONITOR AND/OR COLLECTION WELLS.



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The piezometric gradient increases towards the pumping wells such that the velocity of a slug of water will increase as the wells are approached.

The approximate time required for water to move along its flow path can be calculated from the equation:

$$(2) \quad t = \frac{d}{v},$$

where t = travel time
d = length of flowpath
v = average apparent velocity

Approximate flow velocities and travel times of ground water moving from the landfill to major pumping wells are listed in Table 1. These values have been calculated from Equations 1 and 2 (above) assuming a constant coefficient of permeability of 1000 gpd/ft^2.

These results represent maximum ground water velocities and minimum travel times. Actual rates of flow will be lower where the permeability of the unconsolidated media is less than 1000 gpd/ft^2. The coefficients of permeability of most of the sand encountered during test drilling is estimated at closer to 500 gpd/ft^2, although some gravels had K's of at least 1000 gpd/ft^2. Contaminants from the landfill which enter the aquifer will move most rapidly along the coarsest deposits, while simultaneously spreading throughout the less permeable sections of the aquifer.

The calculations indicate that contaminants leached from the landfill would reach Amoco Well PW-2 in six and a half years. This well has been in production since 1962 so that the gradient between the well and the landfill has probably existed similar to the present situation for more than the calculated travel time. Thus, if the assumptions behind the calculations are correct, contaminants should already have reached the well. However, contaminant travel may have been retarded by sands of relatively low permeability and/or the absence of a direct channel connection between the sands underlying the landfill and those from which water is being withdrawn. In addition, fresh recharge could gain access to the Potomac sands midway along the flowpath in the area where the confining beds

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TABLE I ESTIMATED GROUND WATER VELOCITIES AND TRAVEL TIMES BETWEEN THE LLANGOLLEN LANDFILL AND MAJOR PRODUCTION WELLS IN THE VICINITY

Landfill to Amoco Chemical Corp. Well PW-2 (Flowpath Length = 3360 ft.):

Flowpath Section	I Average	V Average (ft/d)	Approximate t (Days)
Landfill- 960'	.013	1.73	555
960'-2400'	.014	1.86	774
2400'-2880'	.021	2.80	171
[illegible]-3120'	.042	5.60	43
[illegible]-3360'	.083	11.0	22
			1565d=4.29 yrs.

Landfill to Artesian Well Co. Well E-2 (Flowpath Length = 3350 ft.):

Flowpath Section	I Average	V Average (ft/d)	Approximate t (Days)
Landfill- 720'	.007	0.93	774
720'-1360'	.008	1.07	598
1360'-1920'	.009	1.20	467
1920'-2720'	.013	1.73	462
2720'-3000'	.036	4.80	58
[illegible]-3150'	.067	8.93	17
3150'-3350'	.100	13.3	15
			2391d=6.55 yrs.

Landfill to Artesian Well Co. Well #7 (Flowpath Length = 3000 ft.):

Flowpath Section	I Average	V Average (ft/d)	Approximate t (Days)
Landfill-1050'	.008	1.07	981
1050'-2100'	.010	1.33	789
2100'-2800'	.014	1.87	374
28[illegible]'-3000'	.033	4.40	45
			2189d=6.00 yrs.

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are absent, thus improving the quality of water reaching the well. At present, some of this area has been covered by the Delaware Sand & Gravel Company landfill (which can be expected to contribute contaminants to the Potomac aquifer).

The Artesian Water Company has operated large capacity wells at Llangollen Estates since 1953, gradually expanding the number of wells and amount of pumpage to present. Well 7 was constructed on the eastern edge of the old well field in 1969. It is the only well in the old well field still in regular use. The other old wells were replaced by the new well field (including Well E-2) to the east which went into service in 1971. Thus, the steep piezometric gradients towards these wells are a recent development, and projected contaminant travel times must be extended to account for this condition.

Extent of Ground Water Contamination

The approximate extent of contamination in the landfill vicinity has been determined on the basis of analysis of water samples collected from virtually all of the wells in the landfill vicinity in August and September, 1972 and water quality interpretations of geophysical logs run in the test borings during October and November, 1972. The results of water analyses are listed in Table 2. Landfill leachate had affected some well waters mainly as objectionable taste and odor with only slight increases in dissolved solids and dissolved oxidizable material, while in a few cases, dissolved solids and chemical oxygen demand were extremely high and odor was overpowering.

Locations where ground water contamination has been proven or is suspected are shown in Figure 3. The figure indicates that contaminants have, in certain places, already travelled past the test holes most distant from the landfill.

It is estimated that contaminants may be about 2000 feet along the flowpath to Artesian Water Company Well E-2. If so, the contaminants can be expected to reach the well within 400-500 days. Contaminants may also have moved more than 2000 feet from the landfill past the Reni well, but reference to the piezometric map makes it appear that this material is also moving towards the new well field.

TABLE 2

CHEMICAL QUALITY OF GROUND . TER SAMPLES
FROM THE POTOMAC FORMATION IN THE VICINITY OF THE LLANGOLLEN LANDFILL

Well	Date Sampled	Organic Odor	Specific Conductance (µmhos/cm)	COD (ppm)	Cl (ppm)	Σ Fe (visual est.)
Amoco Film Plant #2	9-22-72	~none	100	19	38.1	~none
Amoco Film Plant #3	9-22-72	~none	33	10	15.9	some *
Amoco Film Plant #4	9-22-72	~none	120	<5	13.3	some *
Amoco Polymer Plant PW-1	9-22-72	~none	170	19	13.4	~none
Amoco Polymer Plant PW-2	9-22-72	~none	160	29	45.0	~none
Amoco Polymer Plant PW-3	9-22-72	~none	110	<5	21.3	~none
Artesian Water Co. #7	9-28-72	~none	58	9	7.3	~none
Artesian Water Co. E-2	9-28-72	~none	57	18	8.9	~none
Artesian Water Co. G-3	9-28-72	~none	46	9	4.4	~none
Artesian Water Co. K-1	9-28-72	~none	48	18	4.4	~none
Barrett	9-22-72	~none	120	<5	22.0	~none
Beattie	9-22-72	~none	125	10	26.9	~none
D'Anna	9-22-72	v. slight	100	<5	24.1	~none
Gonzon	9-22-72	v. slight	125	<5	28.7	some
Moose Lodge	9-22-72	strong	140	19	29.2	heavy

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TABLE 2 (Continued)

Well	Date Sampled	Organic Odor	Specific Conductance (µmhos/cm)	COD (ppm)	Cl (ppm)	Σ Fe (visual est.)
V. Dell Aversano	9-22-72	strong	350	19	67.4	some
J. Dell Aversano	9-22-72	strong	350	19	69.2	heavy
Robelens	9-22-72	~ none	80	< 5	18.2	~ none
Reni	9-22-72	v. strong	1300	>1000	124.	heavy
Test Well 1A	8-8-72	~ none	100	--	19.4	~ none
Test Well 2D °	8-30-72	~ none?	250	20	15.9	+
Test Well 3A	9-1-72	v. slight?	1500	49	254.	+
Test Well 4C	9-7-72	~ none	210	30	30.5	+
Test Well 4C	9-28-72	v. slight	240	56	43.7	+

Note

* may be due to infrequent well use

\+ masked by high turbidity

° sample may be affected by residual development solution

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PROPOSED CORRECTIVE PROCEDURES

The present high rate of leachate generation and migration from the Llangollen Landfill must be curtailed immediately. The longer corrective procedures are delayed, the greater the quantity of leachate which must be recovered and treated and the greater the volume of aquifer contaminated--and the greater the expense. Thus, starting in January, 1973, we propose to conduct the following work:

1. Drill 4 wells into the landfill to monitor and control water levels in the refuse.
2. Drill 3 test borings north of the landfill and install piezometers to monitor water levels in the Pleistocene sands and the piezometric heads in the Potomac aquifer.
3. Drill 4 wells immediately south of the landfill to recover leachate from the Potomac Formation which is still close to and concentrated from the landfill.
4. Drill 4 wells at the expected furthest extent of leachate movement towards the Artesian Water Co. well fields for contaminant monitoring and/or recovery.

The locations of all the proposed wells and test borings are shown on Figure 3.

These wells will be pump tested to determine aquifer characteristics and water quality. Wells which can recover contaminants from the aquifer will be designated for that purpose--plans for the disposal of recovered contaminants to be developed when the picture becomes clearer.

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No contamination has been positively identified off the western end of the landfill. Hopefully, the confining beds have not been breached beneath this part of the landfill, and the aquifer will not become contaminated here. Perhaps the Artesian old well field (Well #7) will not be contaminated--at least as long as the new well field continues to withdraw larger quantities of water.

Distributing the present rate of pumpage over a wider area could reduce the hydraulic gradient--and rate of contaminant movement--towards the new well field. This could be accomplished by putting a well at the western end of the old well field (perhaps Well #2) back into production while cutting back on the pumping rates of Wells E-2 and K-1. Although this would allow more time for contaminant interception, such a procedure would result in contamination of a broader portion of the aquifer than is expected under present conditions.

Amoco Well PW-2 has higher than background concentrations of chloride and chemical oxygen demand. These parameters, while not present in sufficient concentrations to be troublesome may have originated at the landfill. Water quality in this well is expected to deteriorate, especially because (as previously mentioned) leachate from the Delaware Sand and Gravel Co. should enter the sandy part of the aquifer, which once served as an infiltration gallery for fresh recharge.

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